



## NASA SBIR 2012 Phase I Solicitation

### A3.05 Controls/Dynamics - Propulsion Systems

Lead Center: GRC

Participating Center(s): AFRC

Propulsion controls and dynamics research is being done under various projects in the Fundamental Aeronautics Program (FAP). For turbine engines, work on Distributed Engine Control (DEC) and Model-Based Engine Control (MBEC) is currently being done under the Subsonic Fixed Wing (SFW) project, and Active Combustion Control research is currently being done under the Supersonics (SUP) project. These 3 efforts are expected to transition to the new Aeronautics Sciences (AS) project in FY13. Aero-Propulso-Servo-Elasticity (APSE) research will continue under the SUP project. Research activity on Controls/Dynamics for electric propulsion systems is expected to be initiated in FY13 under the reformulated Fixed Wing (FW) project. Propulsion control and dynamics technologies that help achieve the goals of FAP, in terms of: reducing emissions; increasing fuel efficiency; tool and technology development and validation to address challenges in High Speed flight; and enabling fast, efficient design and analysis of advanced aviation systems, are of interest. Proposed activities that are compatible with current propulsion controls and dynamics activities supported by the FAP will be given preference. Following technologies are of specific interest:

- *High Efficiency Robust Engine Control* - Typical current operating engine control logic is designed using SISO (Single Input Single Output) PI (Proportional+Integral) control. The control logic is designed to provide minimum guaranteed performance while maintaining adequate safety margins throughout the engine operating life. Additionally, the control logic provides control of variables of interest such as Thrust, Stall Margin etc. indirectly since these variables cannot be measured or are not measured in flight because of restrictions on sensor cost/placement/reliability etc. All this results in highly conservative control design with resulting loss in efficiency. NASA is currently conducting research in Model-Based Engine Control (MBEC) where-in an on-board real-time engine model, tuned to reflect current engine condition, is used to generate estimate of quantities of interest that are to be regulated or limited and these estimates are used to provide direct control of Thrust etc. Alternate methods such as Model Predictive Control, Adaptive Control, direct non-linear control, etc. which will achieve the same objectives as the current MBEC approach while providing practical application of the control logic in terms of operation with sensor noise, operation across varying atmospheric conditions, operation across varying engine health condition over the operating life, and real-time operation within engine control hardware limits, are of interest. The emphasis is on practical application of existing control methods rather than theoretical derivation of totally new concepts. Control design approaches that can accommodate small to medium engine component faults and can still provide desired performance with safe operation are of special interest. The pre-requisite for proposals for engine control design methods is that the NASA C-MAPSS40k (Commercial Modular Aero-Propulsion System Simulation for 40,000 lb class thrust engine) be used for control design and evaluation. This simulation can only be used by U.S. citizens since it is subject to export control laws. Methods for real-time engine parameter identification using flight data are also of interest by themselves.

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- *Distributed Engine Control* - Current engine control architectures impose limitations on the insertion of new control capabilities primarily due to weight penalties and reliability issues related to complex wiring harnesses. Obsolescence management is also a primary concern in these systems because of the unscheduled cost impact and recertification issues over the engine life cycle. NASA in collaboration with AFRL (Air Force Research Lab) has been conducting research in developing technologies to enable Distributed Engine Control (DEC) architectures. The current need is to develop a DEC test-bed which can be used to investigate a wide range of issues such as system robustness, stability and performance of various DEC architectures, the development of network communications requirements, network performance evaluation, robustness of DEC architectures to data transmission faults and impact on system performance. The tools just described must be compatible with the NASA C-MAPSS40k simulation software and easily integrated into the Hardware-in-the-Loop research facility currently being developed under a separate contract. Restrictions on access to these technologies require that any proposed effort will be limited to work being done by U.S. citizens.
  - *Active Combustion Control* - The overall objective is to develop all aspects of control systems to enable safe operation of low emissions combustors throughout the engine operating envelope. Low emission combustors are prone to thermo-acoustic instabilities. So far NASA research in this area has focused on modulating the main or pilot fuel flow to suppress such instability. Advanced, ultra-low emissions combustors utilize multi-point (multi-location) injection to achieve a homogeneous, lean fuel/air mixture. There is new interest in using precise control of fuel flow in such a manner as to suppress or avoid thermo-acoustic instabilities. Miniature fuel metering devices (and possibly also fuel flow measurement devices) are needed that can be physically distributed to be close to the multi-point fuel injector in order to enable the control system to accurately place a given proportion of the overall fuel flow to each of the fuel injection locations.
  - *Aero-Propulso-Servo-Elasticity (APSE)* - The objective of NASA research effort in APSE is to develop a comprehensive dynamic propulsion system model that can be utilized for thrust dynamics and integrated APSE vehicle controls and performance studies, like vehicle ride quality and vehicle stability under typical vehicle maneuvering and atmospheric disturbances, for supersonic vehicles. Innovative approaches to dynamic modeling of supersonic external compression inlets; parallel flow path modeling of the compression and whole propulsion system to accurately model the distortion effects of flexible modes, maneuvering and atmospheric disturbances; and integration of dynamic propulsion models with aircraft simulations incorporating flexible modes, are of interest.
  - *Electric Propulsion Systems* -The objective is to achieve the required increase in the specific power of high efficiency electric components to make a 10 mega-watt onboard power generation and/or utilization feasible for propulsion. Specific areas of interest are: advanced electric power control systems for energy management of battery and fuel cell systems including potentiostatic sensor array to determine battery state-of-charge (SOC) and battery cycle affected state lifetimes; advanced phase angle control systems for electric motors; and advanced power control systems for effective management of large multi-motor arrays designated for use in newer turbo-electric aircraft and embedded boundary layer electric propulsion systems.